D3.2 - WP3 MEETING REPORT

DESIGNING A EUROPEAN EXTRATERRESTRIAL SAMPLE CURATION FACILITY

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European Commission

Authors

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Some of the participants of the EURO-CARES WP3 Meeting (photograph: NHM Vienna, Kurt Kracher).

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Foreword

EURO-CARES (European Curation of Astromaterials Returned from Exploration of Space) is a three year, multinational project, funded under the European Commission's Horizon2020 research programme to create a roadmap for the implementation of a European Extra-terrestrial Sample Curation Facility (ESCF). EURO-CARES team work is organized around five technical Work Packages (WP), led by scientists and engineers representing institutions from all over Europe.

The objective of the WP3 "Facilities and Infrastructures" is to define the state-of-the-art facilities required to receive, contain, and curate extra-terrestrial samples whilst guaranteeing terrestrial planetary protection. All the aspects, from the building design to the storage/curation of the samples are covered by this work package.

The first task of the Work Packages was to conduct an extensive literature review, in year 1 (2015). Then, as the other WPs, WP3 had to organize an international meeting gathering experts to present the work achieved by the WP3 team and to be able to move forward. This workshop was organized by L. Ferrière and A. Hutzler at the Natural History Museum Vienna (NHMV), Austria, in year 2 (2016).

The first day of the meeting (April 13th, 2016) was an expert and team meeting, attended by 28 researchers and engineers. The next two days (April 14 & 15th) were open to the public, with talks organized in four sessions (Curation, Architecture & Design, Cleanliness & Planetary Protection and Manipulation Techniques – Pot-Pourri). A total of 60 people (including 9 invited experts from public institutions, such as NASA, CNES, University of Alberta, etc. and companies such as Merrick Canada ULC, Cleanroom Technology Austria, etc.) attended this part of the meeting. During the "Architecture & Design" session, in addition to the three invited expert talks, the architecture students were able to present their work (three oral presentations, nine posters and 3D models). Finally, a wrap-up expert and team meeting was held on the morning of April 16th.

The keyword of the workshop was "Multidisciplinary". People from a range of backgrounds, expertise and fields of research attended the meeting, resulting in a diversity of knowledge. Presentations were used as a mean of starting discussions on their topics. Coffee breaks, social activities and informal presentations allowed more relaxed and transversal discussions outside of the sessions. The workshop was a very good opportunity for the experts to interact with the students, and for the students to receive feedback from scientists/engineers and to learn from the different presentations given during the meeting. The work presented by the students was acclaimed by all the conference attendees who were impressed by the quality of the presented designs.

The workshop was a very good way to gather a team from all over Europe to work face-to-face and share their progress.

It was also a showcase for EURO-CARES, to make the scientific, technical and political community aware of the project at both international and national levels.

The workshop resulted in a list of major requirements for the facility and a Preliminary Design (D3.1). Areas of the facility design that would require more attention were also identified. All of these are detailed in the report, which is deliverable D3.2 for WP3.

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Acknowledgments

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Anna Berger and Julia Walter-Roszjár, from the department of Mineralogy and Petrography (NHM Vienna) are thanked for their assistance before, during and after the meeting.

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Acronyms

BAP: Biohazard Assessment Protocol.

BSL-4: Biosafety Level 4.

DWI: Double Walled Isolator.

ERC: Earth Return Capsule.

ESA: European Space Agency.

ESCF: Extraterrestrial Sample Curation Facility.

EURO-CARES: European Curation of Astromaterials Returned from Exploration of Space.

HEPA: High-Efficiency Particulate Arrestance.

NHM: Natural History Museum.

RM: Remote Manipulation.

SCF: Sample Curation Facility.

SRF: Sample Receiving Facility.

ULPA: Ultra-Low Particulate Air.

WP: Work Package.

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Expert and Team meeting

The expert and team meeting (in the afternoon of April 13th) was devoted to EURO-CARES Work Package (WP) updates, short expert presentations and open discussions. Main points raised during the afternoon are summarized here:

Work Packages Progress Reports

WP2 "Planetary Protection" (by John Brucato, INAF, Italy, WP2 leader)

WP2 is currently reviewing Planetary Protection policies and working on the organization of the WP2 workshop to take place in June 2016.

In collaboration with WP4, a list of instruments for life detection and biohazard assessment protocol (BAP) is being prepared. Such a list, with characteristics such as size and need conditions is of high interest for WP3.

WP3 "Facilities and Infrastructure" (by Ludovic Ferrière, NHMW, Austria, WP3 leader)

After a summary of WP3, who is involved, the main requirements and important information which has been identified during the literature survey (WP1), the results of the first months of intensive work on this WP were presented. A preliminary concept of the facility, based on the different parts/rooms expected and their characteristics and a detailed list of the persons expected to work in the facility (and respective functions), administrative and science staff, were presented.

WP4 "Instruments and Methods" (by Ian Franchi, Open University, UK, WP4 deputy)

Currently working on a table of information for each instrument required for sample characterisation and curation (with specification on requirements, etc.).

Instruments maintenance is critical, and has to be thought beforehand. Most of an instrument should be kept outside of the contained or clean area, to allow safe and easy maintenance.

WP5 "Analogue Samples" (by Jutta Zipfel, Senckenberg Forschungsinstitut und Naturmuseum, Germany, WP5 deputy)

Analogues can be used:

- For testing instruments and protocols before initial inspection and characterization of the returned samples.
- For testing external laboratories capabilities, through a strict loan protocol.
- As long-term "storage witness samples".

Mirror facility, or analogue laboratory, integrated in the global curation facility. Information about the WP5 workshop to take place in early June 2016 was also presented.

WP6 "Portable Receiving Technology" (by Lucy Berthoud, Thales Alenia Space, UK, WP6 leader)

For a category V restricted mission, the capsule and spacecraft will be engineered so that the probability of a breach upon landing is very low. However, plans including a non-nominal return should be considered.

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Three landing sites are being considered (Utah, Woomera and Cassic Stomr), and pros and cons assessed. On site temporary infrastructures (such as tent, chemical shower, cleanroom, etc.) are being considered. Moreover, a basic design of the box, which should transport the capsule (or the sample container, in case of non-nominal scenario) from the landing site to the curation facility, is under progress.

WP8 "Maximizing Impact" was unfortunately not represented at the meeting.

Discussion

Most of the participants were involved in the discussion and had the opportunity to share their ideas and point of view.

The facility **could be operational even before mission launch**, to undertake flight hardware cleaning, clean flight hardware assembly and archival of spare parts and witness plates.

The community is divided on the question of building one facility able to host biohazardous and non-biohazardous samples at once, or to split the facility and to start with either a non-biohazardous sample curation facility, or with a biohazardous sample curation facility. In the following, we use the term "Restricted" for biohazardous sample curation facility, and "Unrestricted" for non-biohazardous sample curation facility. Building an unrestricted is easier and cheaper than a restricted laboratory, but a restricted laboratory would be helpful to boost the integration of Europe in Mars Sample Return missions. Building a restricted facility a long time before sample return is not recommended, since Planetary Protection regulations might change over time. Retrofitting between contained and non-contained laboratories is time and money consuming, and potentially impossible to complete.

Some technicians can be shared between different laboratories, though BSL-4 technicians are highly trained and specifically assigned to biohazardous samples.

A state of the art facility is not a primordial requirement, first considering that evolution of the technology might be difficult to follow, in term of adapting the facility and then because it would involve too much training for the employees.

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Wrap-up

For more details on each talk, see Appendix.

General comments

- On top of being built at least two years before any sample return mission, the facility could be used for spacecraft clean assembly (as it was done in the case of the Genesis spacecraft), so built and running even before the launching of a sample return mission.
- Sample Receiving Facility and Sample Curation Facility do not have to be built together (and also not at the same time), but from an organizational and architectural point of view it is recommended to build them on the same site, with a common and integrated design.
- Restricted and unrestricted samples will be curated and stored in different laboratories. We do not recommend refurbishing part of the facility but integrating both designs together. Building construction timing can be adapted, with one part being built before the other.
- Complete outsourcing of BAP does not seem to be feasible, considering that existing BSL-4 are not equipped to deal with unknown pathogens.
- New and innovative techniques are to be kept in mind, but these are not absolute requirements.
- Sub-zero temperature for storage and curation should be considered, but that implies constraining additional requirements in the design of the facility and in the choice of materials.
- Requirements have to be sorted in three categories: critical, essential and optional.
- **MODULARITY**: the whole concept will be planned from the beginning, with connected but independent units (e.g. restricted sample receiving facility, unrestricted sample curation facility, etc.). Each unit will be added to the building when necessary.
- To allow modularity (and originally unplanned extensions), a large enough location site should be chosen at first, and kept available over time.
- ESA and other agencies should include construction costs and running costs of the Sample Curation Facility in the mission.
- As for location, the ESCF should be built near an existing facility, accessible (not too far from an airport), not too close to the city centre, in a place with stable political situation, and if possible with limited natural hazards.
- **HABITABILITY**: not really considered in existing facilities but need to be taken into account.
- **SCALABILITY**: important for the evolution of the facility.
- **FLEXIBILITY**: design and construction should aim for flexibility from start.
- Technicians can be trained for different curation laboratories.
- Common tasks can be handled by the same person for different collections (database, maintenance, etc.).
- An external scientific committee should oversee curation and BAP activities.

Keywords: Modularity; Spacecraft assembly

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Infrastructure

Architecture

- Some parts of the ESCF should be visible (and/or "accessible") to the public (VIP tours versus visiting gallery), others must remain hidden. "Open areas" give confidence and is engaging for the public.
- The facility will need a large secondary entrance for new machines to be added or replaced, for the maintenance, etc. This could be combined with the receiving area (high-bay).
- The non-scientific part of the facility should include meeting rooms and social rooms allowing interactions between the different workers (important for the team spirit).
- Design is not compulsory, but not overly expansive, and helps in creating an ideal working environment (functionality and aesthetic aspects are not opposed; both can complement and balance each other). Architects should be involved from the beginning to save time and money.
- A ratio of 3:1 for technical versus curation should be kept.
- Planning is 50 to 70% of the time of the entire project.
- Cleanrooms can be of any shape, to adapt to the requirements/needs (and to the design).
- Servicing should ideally happen outside of the laboratories.
- Animal facility would be one of the different modules, and will be built only if necessary.
- To allow maximum flexibility in furbishing cleanrooms, a high ceiling should be considered (an 8 m-high ceiling is recommended).
- If the facility has several floors, heavy instruments should be easily accessible, hence on the ground. A ramp for trucks should be planned.

Keywords: External maintenance; Architects and Design

Security and risks

- The facility will be equipped with a network of cameras (and monitors) and will have several levels of security.
- The facility should be safe against most probable natural hazards (e.g. hurricane, earthquakes, tsunami, etc.) depending on the location.
- Non location-dependent and non-natural risks (theft, vandalism, terrorist attack, etc.) should also be considered and necessary measures taken.
- The vault should be protected by several levels of security, using for example a system of multiple combination codes (and keys) which is partially known by two different persons, prohibiting a single person to access the vault.
- The vault should not be located underground, because of flood risks (if located in higher floors, other (external) risks should be considered, including aircraft crash, etc.).
- Incipient fire detectors should be placed on the floor of the cleanrooms.
- Water detectors should be placed on the floor of the technical parts and of the cleanroom and dams built around sensitive areas.

Keywords: Natural hazards; Unnatural risks; Fire detectors

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Supply chains

- Nitrogen (N) (or other inert gases, such as argon) can be produced on site or delivered (both options are possible).
- The liquid N tanks and supporting structures should be located outside of the facility.
- N cleanliness should be enhanced by using a well-designed distribution system: seamless, electro-polished and passivated tubing, and a filter just before the processing/storage cabinets.
- N can be re-used/re-circulated or discarded.
- Ultra-pure water (UPW) system must be continuous.
- UPW system must be located on the same floor as the curation laboratories or above it, to avoid on one hand gravity flood and on the other hand the use of a pumping system.
- UPW system should be equipped with UV lights to reduce biological contaminants.
- Air and water handling should be centrally located but there should be distinct systems for restricted versus unrestricted areas, since they cannot be shared.
- High level of redundancy for each system (air, water, power, inert gas, etc.) should be planned.

Keywords: Redundancy; Distinct systems

Cleanliness

- Cleanroom classes can be tested only once the room is fully furnished.
- Materials allowed in close contact with the samples are stainless steel 304, Al 6160 and Teflon.
- Aluminium (amongst authorized materials) is very difficult to clean whilst still avoiding oxidation.
- Cleanliness of inert gas (N and/or Ar) has to be checked for each received batch, and isotope composition is measured each month.
- Weekly particle counts should be done inside the cleanrooms.
- The O_2 and H_2O inside storage and curation cabinets should be carefully monitored, several times per hour.
- HEPA (High-Efficiency Particulate Arrestance) and ULPA (Ultra-Low Particulate Air) filters outgas organic contaminants. Organic cleanliness can be achieved, but only in a restricted area.
- During the construction of the cleanrooms, the level of particles should be monitored, with particles counts, optical inspection and witness coupons.
- To achieve particles and chemical protection a carbon filter should be inserted between two HEPA filters.
- All components of the facility should be monitored for contaminants: lubricants, paint, plastics, etc.
- Suitability tests should be performed on all instruments to be used in a cleanroom of class X.
- Protocols for workers behaviour and for hiring employees should be prepared (e.g. smokers are not allowed in ISO 4 cleanrooms).

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- Instruments in close (/direct) contact with samples should be refurbished with accepted materials.
- Cleanability and chemical resistance of instruments should be known to decide of their position in the rooms.

Keywords: Contaminants monitoring; Working rules

Furbishing of the facility

- Rooms should be equipped with anti-vibration tables and cabinets, using as much as possible anti-static materials.
- Appropriate floor coverings should be used (resistant and easy to clean).
- Lights wavelength should be chosen to have the lightest interaction with the samples. LEDs are a good option, especially if sub-zero T conditions are considered.
- All materials used for building will be screened for contaminants.
- Cleanable/sterilisable cabinet technology will be investigated, to reduce the number of cabinets.

Keywords: Anti-vibration; Anti-static; LEDs

Curation

Manipulation of samples

- Particles with size between ~2-150 µm are easy to handle using a clean tungsten or glass needle.
- Contactless manipulation: optical tweezers (for particles <100 µm); only on low conductors and might heat the particle. Tractor beams (for particles <mm); no heating but need a dense atmosphere. Optical levitation method for larger objects.
- Working practices should be adapted to avoid injury to workers from repetitive tasks or environmental hazards (micromanipulation, noisy environment, suits, etc.).

Keywords: Contactless manipulation

Databasing

- A dedicated software will be designed, and used as a way to collect information and guarantee an efficient management of the samples and allow public outreach.
- Basic requirements:
    - Searchable.
    - Should include a number of sample categories (pristine, analogues, reference samples, allocated, returned, sample preparation, hardware, etc.), with links between them if necessary.
    - Software to be used as a logbook for everything, starting with the landing of the container.
    - Datasets will include identification of the samples, labelling, origin, space mission, imaging, basic characterisation, etc.
    - Dataset relative to the stages of preparation, subsamples, thin sections, etc.
    - Dataset allocated to the physical location of the sample.
- Identification of the collection items can be done through bar codes.

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- Dedicated staff: need of a full time person working on the technical aspect of the database and of a full-time person working on updates and data accuracy.

Keywords: Searchable; User-friendly; Dedicated staff; Flexible

Curation and Storage conditions

- Sub-zero T curation and storage will be considered to reduce organic contamination and alteration of the samples.
- Ar is heavier than air, hence better in case of a leak of a cabinet, and totally inert, but more expansive than N. The use of Ar is recommended on a small subset of the samples.

Keywords: Sub-zero temperature; Different inert gases

Biocontainment & Life detection

- There should be different biosafety levels in the laboratory, for hardware, samples, etc.
- Samples will stay in containment until proven devoid of biohazards or sterilized.
- Scientific community must assess whether animal tissue testing is necessary or not to determine if life is present within the sample.
- There should be three containment barriers at all time around the sample:
  - Primary barrier: personal protective equipment, glovebox.
  - Secondary barrier: room and systems.
  - Tertiary barrier: processes and containment around the system.
- Chemicals for chemical showers must be on top of the cubicles, to use gravity in case of power failure. With an adapted suit, gaseous H_2O_2 could be adapted in a shower cubicle (especially of interest in case of unknown pathogens), although exposure periods would need to increase in comparison to the liquid showering process.
- Self-repairing gloves are being investigated to prevent leaks within cabinets.
- Only the first steps of BAP should be done within an ultra-clean environment (chemical contamination). Some steps can be outsourced or performed in a less clean environment.
- BSL-4 building are either built with concrete walls (especially in US) or using cleanroom airtight panels (preferred in Europe). The pros and cons of each methods will have to be considered.

Keywords: Containment barriers; gaseous H_2O_2, Animal tissue testing

Remote facility

- A location for a remote facility will have to be considered. Remote storage can be storage cabinets at a static pressure, being purged with inert gas once a year.

Robotics

- Robotics should be mainly used for critical activities or for repetitive actions (such as for storage). If samples are limited, robots are not so useful.
- Autonomous robots or remotely manipulated robots need less space than humans but more maintenance is required.
- A design involving robotics will need to show a precise cleanliness analysis (particles, outgassing, etc.).

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Conclusions

The WP3 meeting was a success, with inspiring talks and many engaged discussions. The mixture of expertises and the young audience was very much appreciated. A lot of knowledge was shared, not only during the presentations but also during the question and discussion periods. A certain number of the participants and experts have shared with us their positive impressions about the meeting, and because it would be too long to report on all of them here, we would like to share only one very inspiring comment we have received from one invited expert: "It was very interesting to see how the activities surrounding the Mars sample have changed since we started working on this in 2002...but also a bit remarkable on how much it has stayed the same".

It is now obvious that we will need to define assumptions to be able to move forward. Different scenarios with a list of options will have to be envisaged, allowing us to formulate recommendations.

The need for a glossary was also highlighted during the meeting, to avoid confusions and especially to facilitate discussions of persons with different experience, expertise and backgrounds.

With the key points identified during the meeting, the Work Package 3 team will strengthen its Preliminary Design (D3.1).

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Appendix:

Pictures

EURO-CARES WP3 Experts Meeting at the NHM Vienna (13.04.2016).

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Some of the participants and poster presentations (from the Vienna University of Technology) - EURO-CARES WP3 Open Meeting at the NHM Vienna (14.04.2016).

Presentation of one concept of facility by two students from the Vienna University of Technology - EURO-CARES WP3 Open Meeting at the NHM Vienna (14.04.2016).

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Open meeting minutes

Key points of each talk are listed here. For more detailed information, the abstracts and presentations have been made available on the website:

www.euro-cares.eu/wp3_vienna_proceedings

Please note that key points in italics are not directly relevant for the WP3, but are of interest for other WPs.

SESSION "Curation"

Curating NASA's Past, Present, and Future Astromaterial Sample Collections. Ryan Zeigler (NASA/Johnson Space Center, Houston, Texas, USA) (invited talk)

- The Lunar Receiving Facility was built in three years to be ready two years in advance of the samples return. The scientific community was involved in the planning.
- The building is designed to withstand a Category 4 hurricane.
- There are six levels of security to access the lunar vault.
- There are 30 nitrogen gloveboxes, 10 for processing and 20 for storage. Gloveboxes are kept under continuous flow of ultra-pure nitrogen.
- Materials allowed in the gloveboxes are stainless steel 304, Al 6160 and Teflon.
- For instruments built with non-authorized materials (e.g. microbalances with brass parts), the parts have to be removed, duplicated in an allowed material and then reconstructed.
- Nitrogen is delivered, not produced on-site. The cleanliness of the nitrogen is checked for each batch and the isotopic composition is measured on a monthly basis.
- Laboratory cleanliness is monitored by weekly particle counts. Organic contamination is below 3 ng/cm^3, a low level considering that the laboratory was not built to prevent organic contamination.
- O_2 and H_2O levels are measured four times/hour in the lunar cabinets.
- A strong requirement of the database is to be able to generate relationships between the samples (i.e. parent/daughter/granddaughter).
- Part of the samples are kept in a remote storage at the White Sands Test Facility (New Mexico, USA), in dead-mode cabinets (i.e. static nitrogen storage). The cabinet is purged once a year to protect the integrity of the samples.
- When planning for a building, it is very difficult to foresee technological advances.
- *An educational programme has been developed with part of the samples.*
- *5% of the samples were given away as goodwill samples.*
- *Only 0.3% samples that came back from the Moon was regolith (i.e. dust), the rest were rocks up to half a cm in size. Samples were sieved to split them up into different size ranges.*

Mars Sample Return: End to End Curation from Return to Earth to Sample Distribution - Report from iMARS Phase II. Caroline Smith (Natural History Museum, London, UK)

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- Mars sample return should be international, hence an international scientific committee is recommended. Samples will not leave containment if it can't be proven that they are not biohazardous, or if an efficacious sterilisation method is not identified.
- The facility should have different BSL levels, to host everything that returns to Earth, including hardware.
- Question: Should returned samples go back directly to a sample curation facility (SCF), or to a sample receiving facility (SRF)? SRF should become a SCF.
- *iMars 2 report should be released around July 2016.*

The Maintenance and Development of a Specialised Cold Curation Facility for Pristine Astromaterials. Nicole Spring (University of Alberta, Calgary, Alberta, Canada) (invited talk)

- Curation laboratory is kept at sub-zero temperature to protect low molecular weight organic compounds, hence reducing sample degradation and terrestrial contamination through outgassing.
- Gloveboxes are included within the walk-in freezer. Storage part is kept at -30°C.
- There is no particle filtration in the freezer, since HEPA filters would freeze. Clean air is provided through class 1000 ante-room.
- Gloveboxes are kept under Ar atmosphere. Ar is totally unreactive, and heavier than air, hence behaves better than N in case of a leak (Staff protection measure).
- Fluorescent lights don't work at low T. Laboratory is equipped with LEDs.
- Special gloves made of polyurethane are used.
- Low T is causing issues with precision instruments and with retraction of materials, hence with sealing.
- Low T is a challenging working environment for humans.
- *Vibration isolation tables are required to deal with micro-particles.*
- *The sample holder has to be tailored to aid the transfer of particles, i.e.: to scrape the particle off the needle, you can have a cone like protrusion in the sample holder in order to scrape the needle against it.*

EURO-CARES Extraterrestrial Sample Curation Database: Basic Concepts. Luigi Folco (University of Pisa, Pisa, Italy)

- Need a full time person working on the technical aspects of the database and a full-time person working on updates and data accuracy.
- To make an efficient database, the workflow through the laboratory has to be defined.
- Bar codes can be printed on sample labels/bags/boxes, and bar code readers located in the laboratories, to follow the samples at any time.
- Purpose. A searchable sample database that will be used in EURO-CARES will be designed with the general purpose of i) to collect - and partly make available to the public – information about the curated samples, ii) to guarantee an efficient management of the samples inside the curation and their distribution to the scientific community.
- Sample categories. The sample categories of the database will be: i) Pristine samples (extraterrestrial and analogue samples). ii) Aliquots and preparations for staff training,

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sample classification, and subsample allocation to external laboratories. iii) Allocated and returned aliquots and preparations. iv) residual masses of pristine samples.

- Dedicated software. A dedicated software will be created as a logbook to track and document all the actions performed on the samples and sub-samples inside EURO-CARES and in external laboratories.
- Data sets. The data sets of the database will include: i) Identification (e.g., labelling, origin, imaging, state of matter, mass); ii) Classification (e.g., structural, compositional); iii) Preparation (e.g., type of preparation/mount, preparation/mount description and imaging); iv) location (e.g., sample container/location in the facility). v) Allocation (e.g., requested samples, location outside the curation facility, research purposes & methods duration of the loan/donation, expected results). vi) documentation (e.g. internal/external data and reports, scientific publications). vii) Public (selected data on-line, e.g. sample description and availability for research).
- Actions. All the above information will be obtained and documented during the following procedures/actions: i) Cataloguing (identification, location); ii) Classification (to be meant as preliminary/basic classification); iii) pre-delivery (preparation and allocation). iv) post-delivery (check of returned samples for research, storage).
- Means of data collection. Efficient data collection and storage in the various laboratories of the facility will make use of state of the art electronic devices (e.g., internet, wireless audio-video recorders, bar-coded samples, subsamples and preparations, etc.) enabling unambiguous link of data sets to samples.
- Concept keywords. They include i) simple (input and output); ii) searchable; iii) flexible; iv) user-friendly; v) guidelines; vi) dedicated staff.
- Question: How to handle data homogeneity? Input data should only be a list of accepted names and abbreviations.
- Question: What about maintainability over time? Store a hard copy (paper proof), as at NASA.

Open Discussion on Curation of Extra-terrestrial Samples: What are the Main Issues? (led by C. Smith)

- The scientific community needs to reach a consensus, e.g. on the use of animal tissues.
- What happens if life is detected, and the sample is not already in a BSL-4? Normally this should not happen. The Earth return capsule (ERC) will have a number of fail safes to identify if there has been a breach (non-nominal landing) during landing. Samples will be taken of the landing site that can be stored and analysed if the ERC is discovered to be damaged after inspection at the SRF.

<u>SESSION "Architecture and Design"</u>

Architecture as the Interface between Humans and Technology. Sandra Häuplik-Meusburger (Vienna University of Technology, Vienna, Austria) (invited talk)

- Think about all the possible usages of something, even usages the facility was not designed for (especially true in space).
- Habitability is very important - "Engineering" versus "Architectural" approach.

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- Interdisciplinary works will be conducted in the facility and should be examined from different perspectives to be able to best define habitability.

Three architecture student projects were selected for oral presentations:

Robert Baumgartner & Stephan Asboth (Vienna University of Technology, Vienna, Austria)

- Comment: Avoid having the storage safe underground because of flood risks.
- Question: Is an aesthetic and functional building much more expensive than just a functional one? The design doesn't necessarily result in a really higher price, and can even help with the functionality and evolution of the building in time.
- Question: Should we allow visitors to have a direct line of sight into the labs, or should we use cameras? As in many companies, some parts are hidden, and then there is a visiting gallery in some specific parts. Cameras will be covering the whole facility, for security reasons.

Iina Koskinen (Vienna University of Technology, Vienna, Austria)

- Comment: The design might be a challenge for air and water handling, since it is difficult to keep the machine centrally located, to reduce the length of pipes.
- Comment: More thoughts have to be put in how to bring big instruments inside of the facility, or to allow delivery and maintenance trucks to reach the laboratory parts.
- Comment: There is a need for a clearer plan for all the technical parts in the facility (waste, air, nitrogen, etc.). Most of the systems will have to be separated (BSL-4 and non-BSL-4, etc.).
- Comment: The corridor and the ramp are two key features of the building. They should be even more prominent, with more functions.

Maurice Nitsche (Vienna University of Technology, Vienna, Austria)

- Comment: N tank(s) should be located outside the facility.
- Comment: The cafeteria on-site is a good addition, as is a meeting room for co-workers.
- Question: Why should the building be overly expensive because of design? A well-designed building helps with workers productivity. Cleanroom workers especially need a psychological lift.
- Comment: Good looking building is not always linked to how expensive it is/will be. From a practical point of view, good architects are actually reducing costs, because they see a whole plan, with modularity, how people work, etc. Architects need to be involved from the beginning.
- Comment: Allowing access of the public to some parts of the curation facility is important, and has not been worked on in previous studies.
- Comment: Aren't curvy walls more expensive? Non-squared shaped cleanrooms are more expensive, but might allow to save space for utilities, gases, chemicals, etc.

Risk Based Design of Containment Facilities. Uwe Mueller-Doblies (Epibiosafe Ltd, Woking, UK) (invited talk)

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- Risk tables need to be drawn up with severity vs likelihood, but these are very time consuming and expensive to achieve (see AAHL, Australian BSL-4+ Laboratory). Requirements need to be divided into critical, essential and non-essential.
- Question: How can we benefit from the approach presented for the Planetary Protection aspect of Mars Sample Return? A lot of things we still don't know, very few data are available, especially when it comes to virus.
- Question: What is the acceptability of risks for society and people?
- Question: Costs of the building have to take into account the loss if samples are contaminated.

Facility or Facilities? That is the Question! Michel Viso (CNES, Paris, France) (invited talk)

- There will be an international collaboration over sample return mission(s), hence the necessity of sharing the samples.
- Sample receiving facility vs sample curation facility: Same location? Same facility?
- Mars Sample Return has to be considered as hazardous until proven otherwise.
- There should be only one European curation facility.
- Need to define what is achievable and what is affordable (i.e. cost). **Assumptions should be defined.**
- Question: What is the role of a receiving facility? Exclusively for the opening and then for the distribution of the samples.
- Question: If a sample return mission is handled by different actors, how to decide on the splitting of the sample(s)?
- Question: In your scenario, there is no BAP done at the receiving facility. Samples will be sent to the different curation facilities without knowing if there is a biohazard. What about legal Planetary Protection to transport a potential biohazardous sample?
- *Comment: The concept of redundancy for MSRF is interesting, but might have a heavy effect on payload and on the costs of the mission.*

SESSION "Cleanliness and Planetary Protection"

Evolution of the Lunar Receiving Laboratory to the Astromaterial Sample Curation Facility: Technical Tensions Between Containment and Cleanliness, Between Particulate and Organic Cleanliness. Judith Allton (NASA/Johnson Space Center, Houston, Texas, USA) (invited talk)

- The US Public Health Service defined the requirements for the Lunar Receiving Laboratory (LRL), it was 8,000 m^2 and \$24M. The planetary science geologists defined the requirements for the Lunar Curation Laboratory, it was 1,100 m^2 and \$3M.
- For the LRL, behind the biobarrier were an emission spectrograph, a gas mass spectrometer, an optical microscope and a radiation counting bunker.
- All materials used for the Lunar Curatorial Facility were screened for contaminants.
- The building is built to handle Category 4 hurricanes, with emergency procedures rehearsed each year.
- All other laboratories (Stardust, Genesis, etc.) were established by retrofitting. Retrofitting is a faster and cheaper way, but may not be sustainable in the very long term.

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- ISO Class 4 cleanrooms were used for Genesis. The key element for the cleanroom was the air handlers (ULPA & HEPA filters, with a vertical laminar flow) and installing the nitrogen lines and ultra-pure water system.
- The ultra-pure water (UPW) is energized by ultrasonic or megasonic bath and used to clean the samples and tools. UPW system is equipped with UV light to kill all biological contaminants.
- During the construction of the Genesis ISO 4 cleanrooms, a particle counts was performed every day during construction in order to monitor and to motivate the construction company. Verification methods used were particle counts, optical inspection and witness coupon measurement.
- A Nitrogen purge was required for the interior of the Genesis laboratory to get rid of the ablation gases. (There was a deadline to remove the sample canister from the return capsule as once on the ground, the ablative material slowly heated up the canister and would have possibly reached its temperature limits)
- HEPA and ULPA filters usually off-gas organic contaminants. Organic cleanliness can only achieved locally.
- Incipient fire detectors are located on the floor.
- In some cases, a particle cleanroom is better than a glovebox.
- *BAP on less than 2 kg of lunar rocks (1% of the samples). Tests on "germ-free" mice and fish.*

Human Mars Mission Contamination Tracking. Gernot Groemer (Austrian Space Forum, Innsbruck, Austria)

- Reducing the potential forward and backward contamination – likely to happen for both robotic and human explorers – remains a key challenge for mission designers.
- *Human contamination. It is not conceivable to sterilize the whole spacecraft sent to Mars.*
- *Question: How do you see Planetary Protection constrains evolving? If we want to study life on Mars, we need to send a human.*
- *Question: How to clean the suit from particles? Suits are very fragile, any scratch could cause a leak.*

The Cleanroom Balance. Roman Czech (Cleanroom Technology Austria, Wiener Neudorf, Austria)

- Planning is 50 to 70% of the time of the project.
- Cleanroom requirements have to be defined once the whole room is furnished.
- Question: Sealability of the room? Overpressure?
- Question: Is it possible to build a round (non-squared) cleanroom with a high enough level of cleanliness? Yes, but non-squared cleanroom would be more expansive to construct.

Some Technology Challenges for a Facility Handling Samples from Mars. James "Sandy" Ellis (Merrick & Company, Kanata, Canada) (invited talk)

- Merrick & Company was involved in the NASA Mars Return Facility study from 2002.
- Containment consists of primary (protective gear, gloveboxes), secondary (room and systems) and tertiary (processes and containment around the systems) barriers.

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- Servicing should ideally happen outside the biobarriers.
- Chemicals for showers should ideally be above the showers, not below, as if pumps fail you can still use gravity.
- The minimal area ratio of room needed for equipment to containment laboratories is 3:1.
- Carbon filter is used in between two HEPA filters for DWI (Double Walled Isolator) concept.
- Self-repairing gloves for gloveboxes have been developed.
- Architecture can be designed to remain flexible, hence allowing the facility to stay state of the art over time.
- N_2 production and distribution: N_2 can be produced or purchased. The distribution system must be built to eliminate particles and organic contaminants (seamless tubing, electro-polished or passivated tubing, etc.).
- Question: Would it be possible instead of the shower to have a sterilizing system, such as hydrogen peroxide (H_2O_2) plasma? And to even have such a system inside of the room? With an adapted suit, it should be possible.
- Question: Why was there no robotics in your facility plan? The presented design was put together 14 years ago, but robotics is getting more common nowadays.

Discussion on Cleanliness and Biocontainment (led by Allan Bennett & Thomas Pottage)

- Chemical cleanliness is not important in BSL-4. In which stage of BAP is chemical cleanliness no longer required?
- HEPA filters are doubled for historical reasons. With a reliable enough HEPA filter, there could be only one.
- There might be a public perception issue related to the installation of the facility.
- Has all BAP to be done in the curation laboratory? Can it be outsourced? BSL-4 already existing will not be prepared for an unknown form of life.
- *Is there a study on Lake Vostok's ice core bacteria? Studies were made in Grenoble (France) in a normal laboratory, thus biological contamination was not controlled.*
- *Question: Do we have the technology to study an unknown kind of life, without animal testing? If the life is Earth-like, yes. Animal testing might not be useful, but PP laws still requires it.*

SESSION "Manipulation techniques - Pot-pourri"

Remote Manipulation (RM) System for Mars Sample Receiving Facility (MSRF) - Outline of Activities and Early Results of European Space Agency (ESA) Technology Development. John Vrublevskis (Thales Alenia Space, Bristol, UK) (invited talk)

- Fewer man-in-suit operations (which gives operational flexibility) more robotic manipulation (better containment and lower contamination).
- RM systems should be redundant in some cases to avoid failures.
- There could be a supply of two different inert gases, since it can be connected directly to a mass spectrometer.
- Once a workflow is implemented, a study of risks associated with remote manipulation is needed, with a mitigation of risks.

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Analytical techniques in Double Walled Isolator (DWI) and BLS4+ Sample Return Facilities. John Bridges (University of Leicester, Leicester, UK)

- *Techniques are developed in collaboration with Thales Alenia Space to have a working interface between DWI and scientific instruments, the bulk of the instruments being out of the DWI.*
- *Only a subset of analytical techniques can reasonably be planned for this type of environment (i.e. in DWI).*
- *Analytical workflow inside of the DWI, from sample preparation to chemical analysis. Some techniques requiring heavier instrumentation (Synchrotron, SIMS,…) will have to be conducted outside of the DWI, with an appropriate container, or if the sample is declared non-hazardous.*

Double Walled Isolator (DWI) System for a Mars Sample Receiving Facility (MSRF) - Outline of Activities and Early Results of European Space Agency (ESA) Technology Development. John Vrublevskis (Thales Alenia Space, Bristol, UK) (invited talk)

- Conventional Isolators always leak or are prone to leakage.
- DWI means using mostly remote manipulation or autonomous robots and requires less space because of the absence of humans.
- *Development of pass-boxes, using several approaches (Russian Doll or Top Hat).*

Ultraclean Technologies and Micromanufacturing. Guido Kreck (Fraunhofer Institute, Stuttgart, Germany) (presented by John Vrublevskis).

- Need of the analysis of the cleanliness level of robotic arms, in terms of particles, outgassing, etc.
- Materials used in robotic system have to be monitored: lubricants, surface treatments, paints, plastics, etc.
- Each equipment should be tested for suitability of use in a cleanroom of class X.
- Cleanability and chemical resistance of surfaces have to be considered for instruments and overall rooms.

Robotic Handling and Robotic Inspection - Profactor's Expertise. Gerald Fritz (PROFACTOR GmbH, Steyr-Gleink, Austria)

- Different usages and various possibilities of robots.
- The advantages and disadvantages of using robots was discussed; "Pro and cons of robots".

Manipulation of Samples in Mini Environments. Peter Mani (TecRisk, Bremgarten, Switzerland) (based on ppt. presentation only)

- Fully automated storage systems at appropriate conditions.
- Robotic handling of the samples with barcode reading.
- More work is needed to adapt micro-robotics to be able to manipulate pristine samples.

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Industrial Sample Preparation for Electron Microscopic Investigations. Robert Ranner (Leica Microsystems, Vienna, Austria)

- Specific instruments were presented, including sample workflows.
- Sample transfer (contamination-free) solutions were presented, allowing to link workflow from preparation to analysis.

Optical Micro-manipulation: A primer. Siddarth K. Joshi (Institute for Quantum Optics and Quantum Information, Vienna, Austria)

- Using laser to move particles without any contamination. Systems are relatively unexpansive (50-100K€) and the instrument can stay outside of the sample container if there is a window to allow laser light to go inside.
- Optical tweezers can handle particles up to 100 µm in size, and down to the atomic scale. Not possible to manipulate good electric conductors (metals) particles. Might heat the particles.
- Tractor beams heat a cushion of air, to make a particle up to mm move. Need of a dense atmosphere, but no direct heating of the particle.
- Optical levitation allows handling of really large objects (up to kg), but has a lot of limitation (needs high power, very unstable, etc.).
- Need of models to calculate the increase of temperature considering the type of particles, the environment (air versus inert gases), the power of the laser, etc.

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